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The geology of an area near Shabani, Rhodesia, with special emphasis on an occurrence of younger granite

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Hornblende Lamprophyres.

Occurrence.

Lamprophyric dykes within the younger granite were intruded almost exclusively along distinct dilatational fractures orientated at right angles to the elongation of the granite body, and along major joint planes. Therefore their strike on the granite is roughly N50-60W, but approaching the margin of the granite they swing into a due north strike, conforming to the gneiss foliation direction. The dykes, whose width ranges from ½ inch to 6 feet and dip vertically, have been traced for distances of only 300 feet away from the granite contact. They are thus almost exclusively confined to the granite.

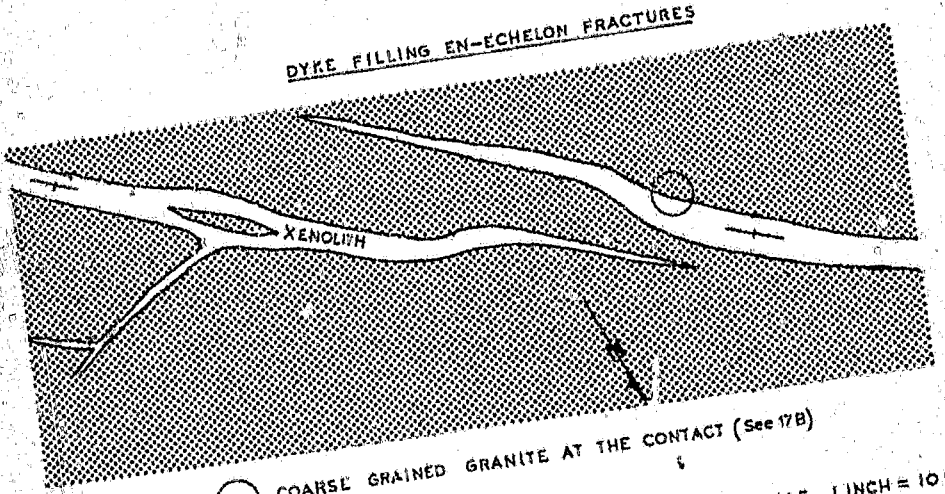
Composition.

The dykes range in composition from a quartz-rich-hornblende granite to a quartz-hornblende syenite. The range in composition based on volume analyses is as follows:- quartz 7-84%, microcline-microperthite and plagioclase 4-35%, hornblende 12-56%, iron ore minerals 1-3%. It is significant that the lowest quartz count of 7% was associated with the highest felspar count (predominantly microcline-microperthite) of 35%, and the highest hornblende count of 56%. This composition, based on a thin section taken from the centre of a large dyke, is thought to represent

Figs. 17A & B.

FIG 17A

DYKE FILLING EN-ECHELON FRACTURES



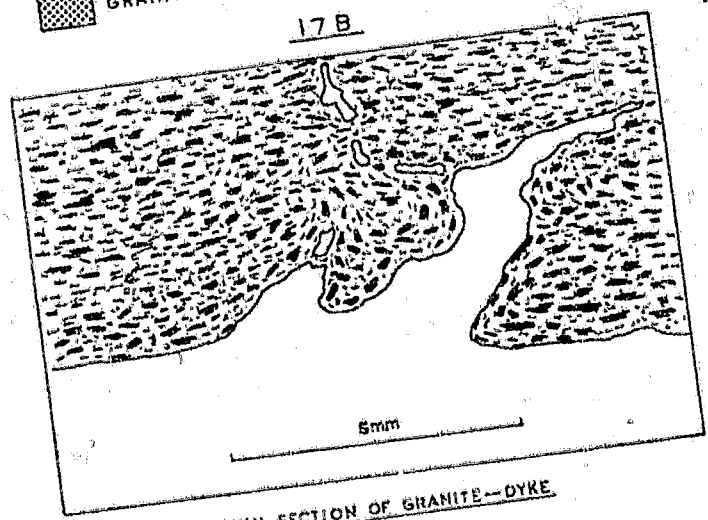
COARSE GRAINED GRANITE AT THE CONTACT (See 17B)

SCALE 1 INCH = 10 FEET

LAMPROPHYRE DYKE

GRANITE

17B



THIN SECTION OF GRANITE—DYKE CONTACT

AMPHIBOLE CRYSTALS SHOWING FLOW DIRECTION OF DYKE

GRANITE

the uncontaminated lamprophyric material.

Narrow dykes usually have the composition of a hornblende granite, which is also the composition of marginal contact zones in the wider dykes. When the main mass of the dyke is poorer in quartz but much richer in hornblende and microcline-microperthite, contamination by the adjacent granite must have taken place.

Emplacement.

The dykes were intruded when the granite had more or less completely crystallised. This is proved by the following observations:-

(1) Granite xenoliths occur in the dykes, often as angular fragments, and also as partially digested material.

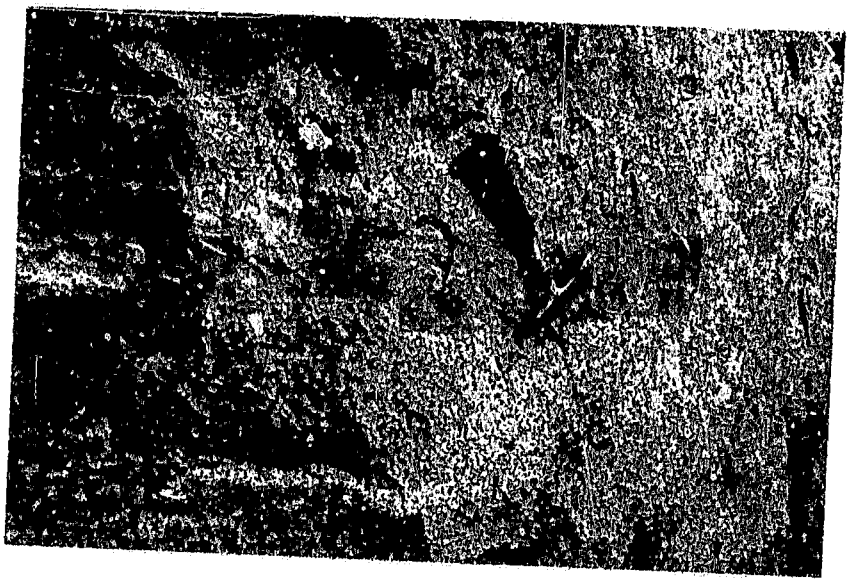
(2) Flow structures are observed in the wider dykes, with hornblende and felspar showing a preferred flow orientation parallel to the margins.

(3) Chilled contacts occur against the granite host often associated with minor assimilation of the granite wall.

(4) Dilatational fractures can occur only after almost complete solidification of the granite at that horizon. Such fractures are frequently arranged as en-echelon tension gashes along which dykes have been emplaced (Fig. 17).

(5) Offshoots from the dykes frequently follow minor joint patterns; this again could only happen after more or less

Plate 22.



Slight displacement of a lamprophyre dyke, not reflected in the bordering granite.

Plate 23.



Displacement of the granite and lamprophyre dyke along a curving irregular fracture.
Maximum width of dyke = 18 inches.

complete solidification of the granite.

The following points are at variance with this deduction:-

(i) Some of the dykes are faulted. The dislocating fractures, while clear in the dykes, frequently cannot be observed in the neighbouring granite (Plate 22). Such features have been observed in other regions, (Bridgewater 1963, Watterson 1962); it is thought that subsequent healing took place in the granite. This definitely appears to have been the case at Shabani, where recrystallisation of the granite in line with the dislocating fracture plane is indicated by a slight increase in grain size.

(ii) Pinching and lensing of the dykes are common features, but it is thought that these are caused by pre-dyke structures in the granite.

(iii) In thin section it can be frequently seen that quartz and felspar crystals from the granite sidewall have been incorporated in the dyke material. This is explained by heat from the dyke remobilising the granite at the contact to form a crystal mush, which has been drawn into the dyke by flow movements operating in the molten dyke, termed back-veining (Fig. 17).

Origin.

The dykes are clearly associated with the younger granite. Similar dykes have been observed in other regions,

where it has been generally agreed that they have intruded along shrinkage fractures, resulting from the cooling of the granite. This is quite clearly demonstrated in the Shabani younger granite as already outlined.

Whether the more basic material, relative to the granite, represents a differentiate from the magma, perhaps of palingenetic origin (Dietrich 1960), the intrusion of fused basic country rock along deep-seated shear zones (Watterson 1962), or the reappearance of a basic front, formed during migmatisation and granitisation at depth, is purely within the realms of speculation.

The association of hornblende with microcline-microperthite, and the evidence for the quartz content having been initially low in the dyke, leads the writer to believe that the dyke formed either from a more basic differentiate at depth of the granite itself, or contamination of granite magma by digested basic country rock.

The lamprophyres are contemporaneous with the aplite and pegmatite dykes in the granite. If there has been a separation of the granite magma during emplacement into alkali felspar-rich and quartz-rich fractions, there can be no objection to a further division into a felspar-amphibole fraction occurring at depth.

Plate 24.



Micrograph of graphic granite (runite). Quartz is in extinction. Light coloured mineral mainly microcline-microperthite. X 22. Crossed nicols. Slide X 4264.

Plate 25.



Micrograph enlargement of plate 25, showing the angular relationship of quartz (white) in microcline-microperthite. X 60. Crossed nicols. Slide X 4264.

Plate 24.



Micrograph of graphic granite (runite). Quartz is in extinction. Light coloured mineral mainly microcline-microperthite. X 22. Crossed nicols. Slide X 4264.

Plate 25.



Micrograph enlargement of plate 25, showing the angular relationship of quartz (white) in microcline-microperthite. X 60. Crossed nicols. Slide X 4264.

Description of Pegmatite and Aplite Occurrences.

These rocks, described below, are associated with the intrusion of the younger granite.

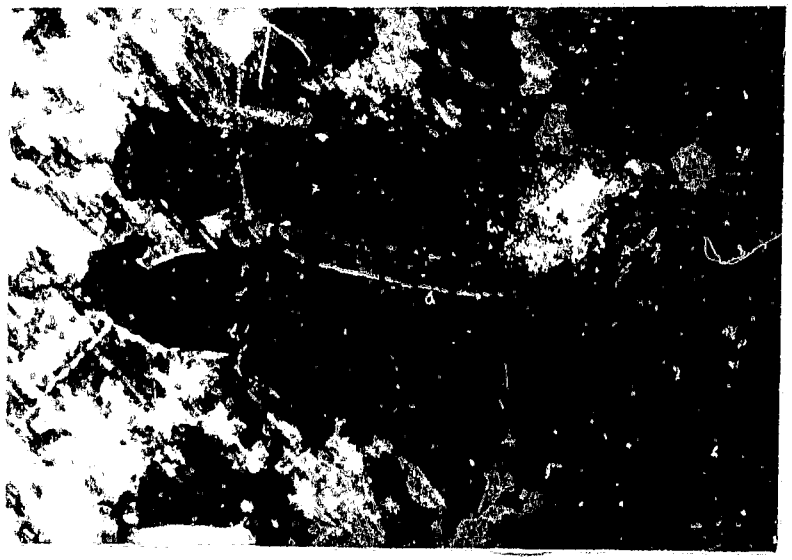
Graphic Granite.

Although this rock is no longer recognised as a true pegmatite as defined by Haüy (Hatch, Wells & Wells, 1952), it has formed from a residual granite fluid, and is frequently associated with aplites and simple pegmatites at Shabani. This distinctive runic texture (Plates 24 & 25) is a common feature near the contact of large granite dykes with the gneiss. It has also been observed at the aplite contact with the granite, the granite/gneiss contact, and forms the marginal zone of the granite tongue (Fig. 18 and Plate 1).

Narrow graphic granite veins have been found in the granite and in the gneiss. Volume analyses carried out on samples taken from both areas, show that the ratio of quartz to felspar (mainly microcline-microperthite), is 32:68 for the granite areas and 39:61 for graphic veins in the gneiss. The modal counts of felspar and quartz in the graphic pegmatites found on the granite, are nearer to the constant ratios of 30:70 observed by Hatch, Wells & Wells, (op.cit.), who suggest that this ratio is the result of crystallisation of a eutectic mixture of the two components.

In most thin sections the host felspar is a pink

Plate 26.



Micrograph of graphic granite showing an ex-solution rim of quartz (a), at the quartz (black mineral) microcline-microperthite border. X 60. Crossed nicols. Slide X 4653.

Plate 27.



Narrow pegmatite vein with graphic borders, in granite.

microcline-microperthite which occasionally shows a reaction rim with the quartz. This rim, which appears to be exsolved felspar, probably represents the residual liquid after eutectic crystallisation (Plate 26).

The angles observed between the quartz and felspar vertical axes varied from 72-76° for four determinations, as against 70° recorded by Fersmann (Hatch, Wells & Wells, op.cit.).

One felspar crystal was left unidentified. This occurred in a thin section of a graphic pegmatite vein in the gneiss, near the Ngomé granite contact (Fig. 1). It appeared to be an untwinned microcline, but optical measurement of 2V gave a range of 74-78°, i.e. intermediate between microcline and orthoclase.

Plagioclase traces occurred in all samples examined, but did not exceed 1%. The plagioclase was identified as albite-oligoclase, having on average a lower anorthite content (11-13%) than that found in the granite.

Simple Pegmatites.

These occur in the granite and in the gneiss as narrow dykes, less than 3 feet wide, striking in a northerly direction with a vertical to 80° dip east. They are frequently associated with aplites, with which they form striking features that can be traced across the gneiss to

the Shabani Ultrabasic footwall contact. On the granite, narrow pegmatite veins grade imperceptably into a coarse to medium-grained granite, with a simple phaneritic assemblage of quartz and felspar (Plate 27).

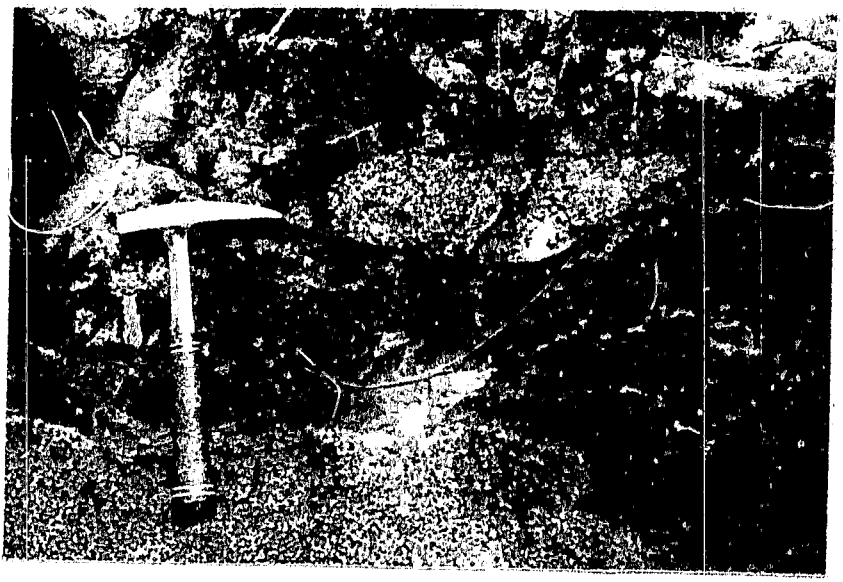
In hand specimen, the rock has a pink colour when fresh due to a predominence of microcline-perthite. The other minerals present are essentially the same as found in the main granite, i.e. quartz, oligoclase and muscovite. Pneumatolitic minerals, apatite and tourmaline, occur in isolated concentrations.

Muscovite occurs as a film coating fractures and joint planes. Occasionally it may form small books of mica in vughs and open fractures. The mica plates are usually slightly curved, indicating minor post-crystallisation pressures.

The quartz is the normal greyish-white variety, and is frequently euhedral, especially when associated with aplitic material.

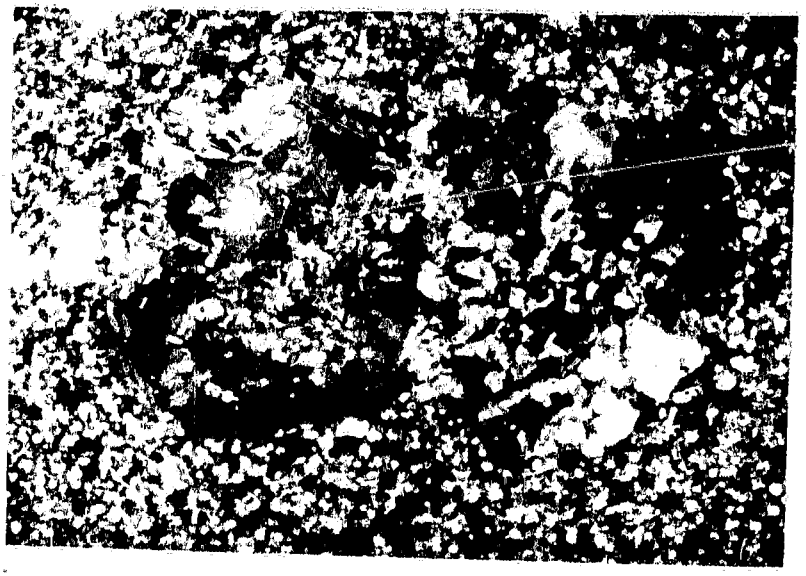
Both the felspar minerals are commonly euhedral, with plagioclase and microcline-perthite frequently forming, together with quartz, perfect euhedral phenocrysts in an aplitic groundmass. The felspars are normally partly sericitised, with this mineral preferentially attacking the felspar along cleavage planes and fractures.

Plate 28.



Aplite vein cutting granite (mottled), and enclosing a xenolith of granite. Xenolith is parallel to the aplite strike indicated by the direction of the hammer.

Plate 29.



Micrograph of Plate 28, showing the granite xenolith in a fine grained aplitic groundmass. X 40. Crossed nicols. Slide X 4655.

Aplites.

This rock type is commonly found in the granite, in the gneiss bordering the granite, and underground on Shabanie Mine. They are frequently associated with pegmatites, forming composite veins, and as pure separate intrusions which may be found several miles from the granite contact. They consist predominently of quartz. Volume analyses showed quartz to be constantly in excess of 70%, with a fine saccharoidal texture. This rock is therefore hard and compact, and is extremely resistant to erosion. Sulphides are commonly found, principally pyrite, which due to the preferential weathering is normally leached out, giving the rock a porous, pitted appearance.

Aplite dykes rarely exceed 6 feet in width, and are normally 1-3 feet wide, with a near vertical dip. Narrow 'stringers' of aplite may form offshoots from the main dyke. These narrow veinlets appear to have preferentially followed joint planes and fractures, and may completely enclose small bodies of granite by rejoining the main dyke (Plates 28 & 29).

The dykes range in colour from a fine saccharoidal pure white form, to a grey glassy rock. The latter could be termed a felsite and occurs usually in the gneiss, passing into the whiter form along strike as the granite contact is approached.

Aplite sills, though rare, have been observed on the

granite and also near the crest of the Prince of Wales range. These hills, which represent an outlier of the Shabani Ultrabasic complex, are not shown on either of the maps, for they occur approximately 6 miles from the nearest granite exposure. The sill, which is 20-30 feet thick, forms a resistant capping to one of the smaller peaks.

The aplite is often coated with a brown stain, due to the decomposition of pyrite and the rare chalcopyrite. Many pits and trenches across these veins, are evidence of the false hopes that this limonitic staining has brought local prospectors. Because of their durability, outcrops of aplite have very often been used by the 'ancients' for milling and grinding purposes.

Aplites associated with pegmatite, may replace the earlier formed quartz and felspar phenocrysts. In several localities on the granite, almost complete replacement of these minerals has occurred, and only the skeletal crystal outlines remain as evidence of their former structure.

In the east central granite area (Fig. 2), a plug of aplitic material has stoped its way upwards through the granite. This irregular mass had initially been injected along major joint planes in the granite, it then expanded by infiltration along minor joints and fractures. The final aplite intrusion has therefore a highly irregular border relationship with the granite. The main implication

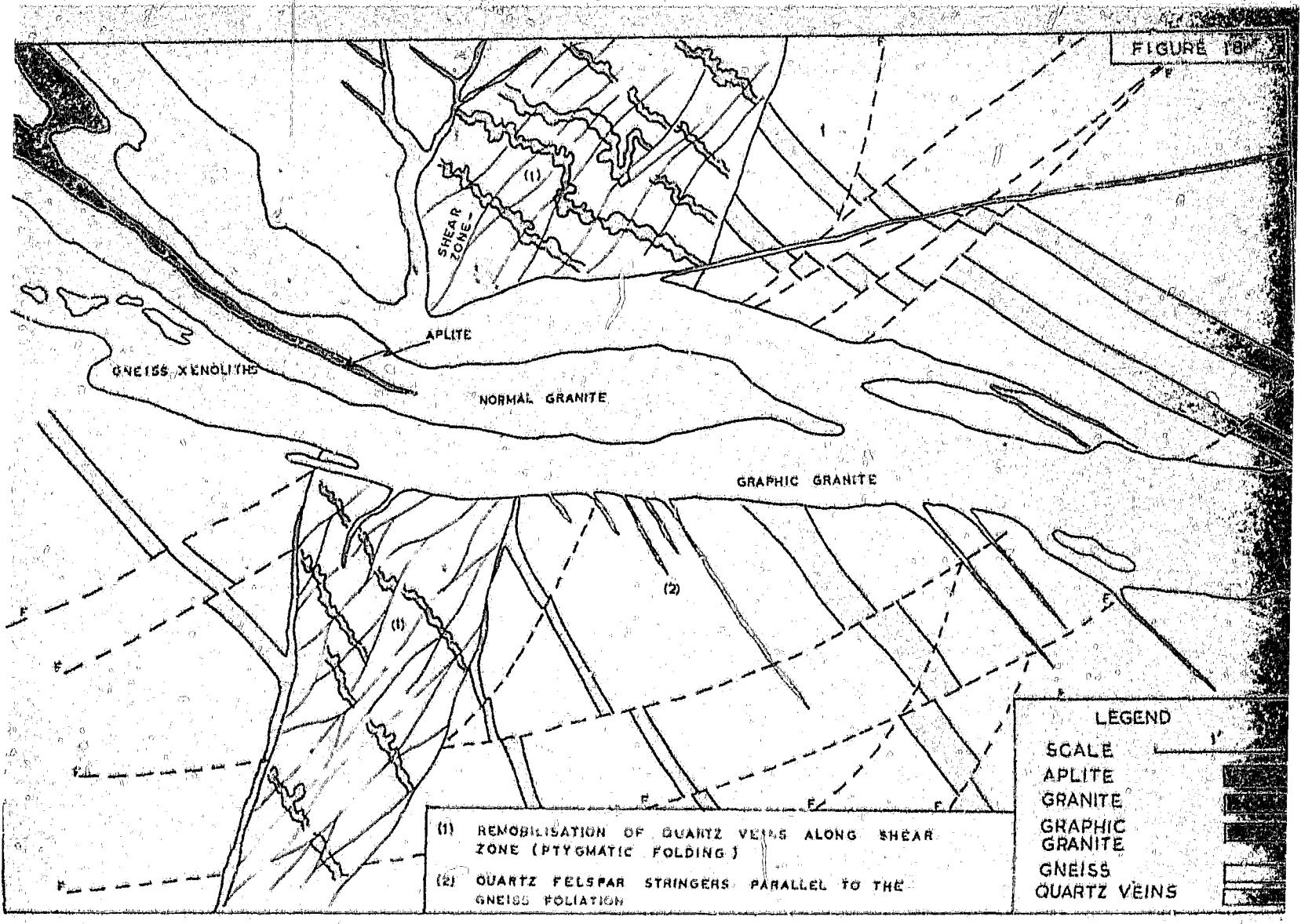
deduced from this feature, is that the aplitic material must have been either volatile, or a highly mobile fluid. The emplacement of this small aplite body has therefore many features comparable with the main granite emplacement.

Differentiation of aplite from granite has frequently been observed in large granite veins in the gneiss. This process has led to the complete segregation of aplitic material, with its final intrusion as aplite dykes. Therefore, at Shahani, it appears that the aplites are of the normal type in that they are derived from the crystallisation of a granitic melt, representing a residual fraction, which if a fluid, has an extremely low viscosity.

The Association of Pegmatite with Aplite.

This association is a common relationship with the fine grained aplite material normally forming the core of the vein. It is thought that the aplite represents the remaining fluid after crystallisation of the pegmatite, and its granular texture is either due to the exhaustion of the 'fluxing media', or to the escape of volatiles during the crystallisation of the pegmatite. An escape of volatiles undoubtedly occurs, as evident by the formation of muscovite along fractures. The residual solution would therefore become relatively dry, forming a suitable fraction for the formation of aplite.

Fig. 18.


FIGURE 18
SHEAR ZONE
(1)
APLITE
GNEISS XENOLITHS
NORMAL GRANITE
GRAPHIC GRANITE
(2)
(1) REMOBILISATION OF QUARTZ VEINS ALONG SHEAR ZONE (PTYGMATIC FOLDING)
(2) QUARTZ FELSPAR STRINGERS PARALLEL TO THE GNEISS FOLIATION
LEGEND
SCALE 1"
APLITE
GRANITE
GRAPHIC GRANITE
GNEISS
QUARTZ VEINS

It is doubtful whether the aplite could form a separate, later intrusion along the centre of a pegmatite vein, often following the irregularities of the outer pegmatite sidewall. This structural relationship must represent a drop in temperature, coupled with a changing composition, leading to the formation of an aplitic core which would still be fluid and exhibit flow features.

Volume analyses of specimens taken across a wide granite vein or tongue Fig. 18, indicate a marked increase in quartz towards the centre, and a corresponding decrease in felspar. These results are tabulated below, and it is thought illustrate the extreme mobility of the granite magma.

	Quartz	Rest (mainly felspar)
Graphic granite border.	31	69
Medium grained granite.	39	61
Aplite core.	77	23

Many occurrences show that it is impossible to disassociate pegmatite from aplite, either in the granite, or in the country rock neighbouring the granite. Occasionally the aplitic material has replaced euhedral felspar and quartz crystals in the pegmatite, indicating two separate phases. This age relationship is also verified by the narrow veinlets of aplite that traverse

fractures in the pegmatite. Complete separation of aplite from pegmatite has occurred, as evident by the numerous aplite dykes. Therefore, minor movements must have taken place during the crystallisation of the pegmatite and granite, whereby the aplitic material was concentrated, possibly draining through fissures, and finally due to local readjustment, injected into late fractures and joint planes.

Shabanie Mine Pegmatites and Aplites.

On Shabanie Mine pegmatite and aplite veins occur, which appear to be contemporaneous with the chrysotile formation. These veins are completely altered where exposed in underground development, although pink felspar crystal outlines can be identified in hand specimens collected from 'H' - Lode, Nil Desperandum Section. In thin section, the only mineral identified in the pegmatite from 'H' - Lode was sericite pseudomorphing felspar.

Several pegmatite and aplite veins have been mapped underground, and it is thought significant by the writer that their strike and dip parallels that of the talc zones, although their width is considerably less. They persist for several hundred feet along strike and down dip, and like the major talc zones with which they appear to be associated, displace the earlier diabase dyke formation.

Pinching and swelling of these veins are a normal feature, though rarely exceeding four feet in width. Pale green serpentinisation of the dunite occurs adjacent to these veins, and this is identical to the serpentinisation surrounding chrysotile fibre seams. Furthermore, aplite and pegmatite rocks have been found in talc zones, e.g. Zone C.

Correlation of the Shabanie Mine Aplites and Pegmatites with those derived from the Younger Granite.

The granite outcrops 7 miles away from the main Shabani mining area, although underground this distance could be considerably less. Nevertheless quartz, aplite and pegmatite veins can be traced from the granite to the Ultrabasic complex, particularly in the western area; therefore it is proposed that all the aplite and pegmatite bodies found underground on Shabanie Mine are associated with the granite emplacement. They cannot be derived from an earlier acid intrusive phase, for they traverse the Ultrabasic complex, and displace the later diabase dykes. Furthermore, they are not associated with a later acid phase, for they are contemporaneous with the talc zone and fibre formation period.

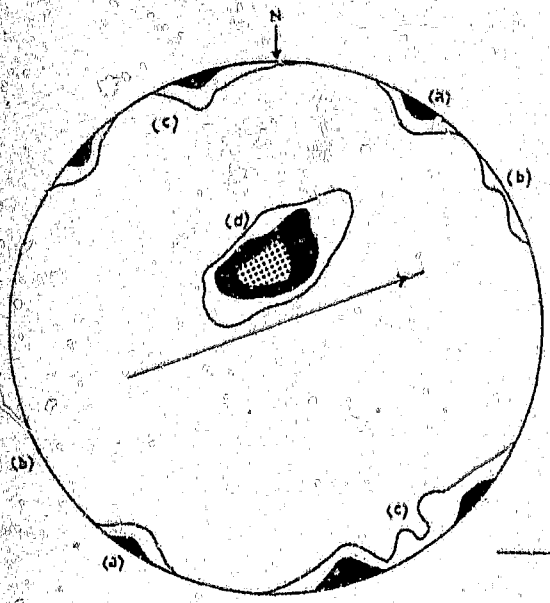
It is therefore concluded that, beyond all reasonable doubt, the pegmatite and aplite veins found in the Shabani

Ultrabasic are associated with, and have been derived from the younger granite intrusion. The reason why their strike and dip in the Ultrabasic should differ from their direction in the gneiss, is due to the established N-S fracture pattern in the gneiss parallel to the foliation, and in the Ultrabasic a NW-SE pattern parallel to the strike of the intrusion. This change in strike and dip has been put forward as a possible explanation for the disappearance of prominent late N-S trending quartz veins at the Ultrabasic/gneiss contact, and the emergence of NW-SE talc zones of equal magnitude in the Ultrabasic, (see later description of quartz veins).

Figs. 19 & 20.

FIG 19

STEREOGRAM ANALYSES OF JOINTING IN THE YOUNGER GRANITE



267 POLES

GRANITE EAST OF THE BANDED IRONSTONE 'RESISTOR'

>3% CONTOUR OF JOINT PLANE POLES

3% "

2% "

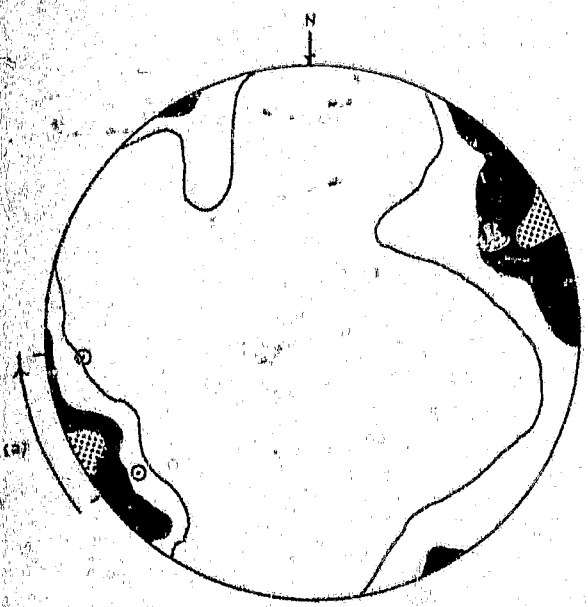
1% CONTOUR NOT SHOWN

(a)&(b) TENSIONAL JOINT DIRECTION

(c)&(d) LONGITUDINAL JOINT DIRECTION

DIRECTION OF ELONGATION OF THE YOUNGER GRANITE

FIG 20



142 POLES

GRANITE WEST OF THE BANDED IRONSTONE 'RESISTOR'

>2% CONTOUR OF JOINT PLANE POLES

2% "

1% "

BEDDING PLANE POLES OF THE BULAWAYAN ROCKS

STRUCTURAL AND ECONOMIC SECTION.

Introduction.

During the mapping of the granite and gneiss, although major trends were observed and recorded, all joint directions were mapped in order to eliminate subjective selection and to obtain an impartial result. In the case of the granite, the results were initially plotted on the lower hemisphere of a Wulff equal angle net, to see if any concentric arrangement would appear. The results were then plotted, for the gneiss (Fig. 21) and granite (Figs. 19 & 20), on a Schmidt equal area net and contoured.

Anomalies arising during the collection of fracture data, e.g. omission of fractures parallel to the foliation, the weighting of large and small fractures, and variations in field technique and efficiency over a long period, were noted, and may account for the occasional random plot, but these are felt by the writer to be at a minimum.

Structures in the Granite.

Tension Joints.

No evidence was observed in the field of linear or platy flow structures in the main granite, i.e. flow lines as indicated by parallelism of phenocrysts, needle-shaped crystals, spindle segregations, clots or xenoliths. Therefore cross joints, as strictly defined by Balk (1937),

cannot occur, i.e. those joints that are arranged perpendicularly to primary flow structures. The long, regular, and prominent joints, that strike at a large angle to the long axis of the granite at Shabani, have been termed tension joints, and in a broad sense are identical to cross-joints. In the western area the joints dip consistently eastwards at a steep angle, which towards the centre of the granite becomes nearly vertical. The eastern area has a lower percentage of exposed granite, but the dip again is nearly vertical. As the margin of the granite is approached, the tension joints become tangential to it. This is particularly noticeable in the well exposed western area.

The tension joints fall into two main sets, a 320°-350° striking group generally dipping steeply east, and a 275°-295° group which are normally vertical in dip. Statistically, the 320°-350° set predominate in the western area. These relationships are discernable on the main structural map (Fig. 2), and are plotted on the stereographic projections (Figs. 19 & 20).

Aplites on the granite tend to align themselves parallel to the 320°-350° set, whilst the basic dykes generally follow the more westerly set. The two sets of joints obviously formed at approximately the same time, for in the centre and north of the body the aplites cut

the basic dykes, whilst in the south the opposite relationship holds. It is believed that the retaining forces operating in the foliated gneiss were slightly different from those in the Bulawayan sediments, and this variation has been reflected in the two sets of tension joints in the granite.

Although flow lines have not been identified on the main granite, the granite veins that are found at the contact have flowed outwards from the granite, decreasing in width as they are traced into the gneiss. Therefore, if the granite had been primarily emplaced by a vertical intrusion of granitic material along a major crustal tension joint, striking NE-SW, then the granite, on reaching its roof elevation, must have expanded radially outwards from the fracture to form its present elongated outline. Increasing upward surges of the melt would have their greatest effect along the line of the original fracture, creating prominent linear tension joints, or 'Q' joints (Cloos, 1923), in this area. These would be well developed in the centre, for in this region the interior would still be partly molten, and therefore assist in the dragging open of the tension joints in the frozen shell, the greatest movement being along the long axis of the granite. These joints would tend to diminish outwards towards the granite margin, where the horizontal force component would be resisted by

Plate 30.



Longitudinal jointing in granite. Flatter plane inclined NW and steeper plane inclined SE. Length of photograph 16 feet.

consolidating magma. As this change took place, so the strike of the tension joints would alter, and may have become influenced by other jointing processes, e.g. longitudinal joints and marginal joints.

Longitudinal Joints.

These joints strike parallel to the long axis of the granite, and have been plotted on a stereo net (Figs.19 & 20). They are frequently composed of two planes, with the flatter plane dipping NW at 30° on average, and the steep plane dipping SE (Plate 30). Reference concerning longitudinal joints or 'S' joints have not satisfactorily explained their origin, e.g. Balk (1937) and Hills (1957). It may be significant that the inclination of the two sets at Shabani, i.e. to the SE and NW, is parallel to the roof of the granite, which slopes gently to the NW and steeply to the SE.

If they are fractures formed by the simple upsurge of magma as suggested by Balk, they should have one steep plane dipping parallel to the vertical force component. However, if the granite is confined, and the rock resists plastic flow, two sets of shear zones would occur; these could be correlated with the two dip directions observed at Shabani, providing the main upward compressive force was inclined at $\pm$ 60° to the NE. Furthermore, this would imply that

the main granite intrusion was similarly inclined, unless there has been later crustal tilting of the area in this direction. As the granite contact is approached, the joints frequently show a slight curve parallel to the contact. Dyke material may form along the steeper joint surface, usually as an offshoot from the main tensional dyke direction.

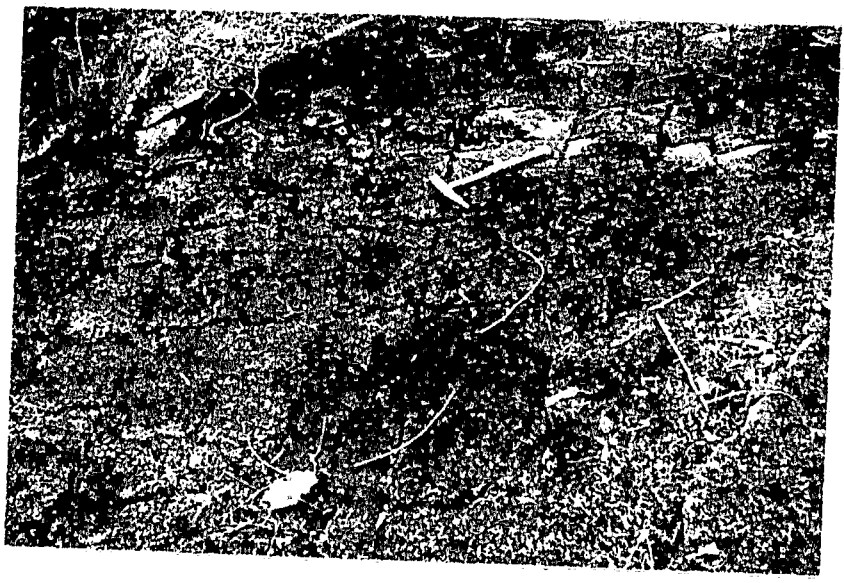
Flat Lying Joints.

These joints are probably normally the result of exfoliation, except where weathering has produced a castellated feature; in the latter case, the flat lying joints visible in the vertical cliff sections could represent a primary fracture. As a result of the lack of association of these joints with contemporaneous or later granitic intrusives, e.g. aplite, quartz veins, etc., and considering the relatively few good exposures, the joints are taken to represent load release fractures, resulting from the erosion and removal of overlying material.

Pavement Fracturing and Cone Fracturing.

In certain flat, well exposed areas on the granite, there has formed a rigid, geometrical pattern of closely spaced fractures, intersecting at right angles. This grid pattern is formed of rectangles 6" x 9", and appears

Plate 31.



Pavement jointing in granite.

Plate 32.



Radial cracks converging on a small depression in the granite.

similar to an artificial pavement (Plate 31). It is thought to have resulted from the weathering of a flat surface. This is a minor feature only, and is not typical of the normal granite surface; but it must reflect a linear structural weakness in the rock. This could develop during the cooling of the granite, if the loci for crystallisation were spaced at regular intervals.

Cone fractures (Plate 32), are again a minor feature, consisting of a small 6"-12" diameter crater from which radial cracks have developed. The lip of the crater may be an inch above the level of the granite surface. Probably they merely represent potholes forming on a flat surface, although a comparison could be drawn with the fracture pattern formed after a bubble of thick mud had burst.

These minor features in themselves are not important, but it is thought that they add further weight to the hypothesis of a magmatic emplacement of the granite.

Late Fractures.

Two types have been recognised.

(a) These traverse all earlier structures in various directions, although a NE trend appears to dominate (Fig. 23). They can frequently be traced over a considerable length of strike. Thin sections of granite bordering these fractures

Plate 33.



Micrograph of granite, showing early fracturing of plagioclase lamellae, not reflected in the encompassing minerals (mainly microcline-microperthite). X 26. Crossed nicols. Slide X 4805.

Plate 34.



Micrograph of narrow granite vein cutting earlier microcline-perthite phenocryst (m). X 26. Crossed nicols. Slide X 4684.

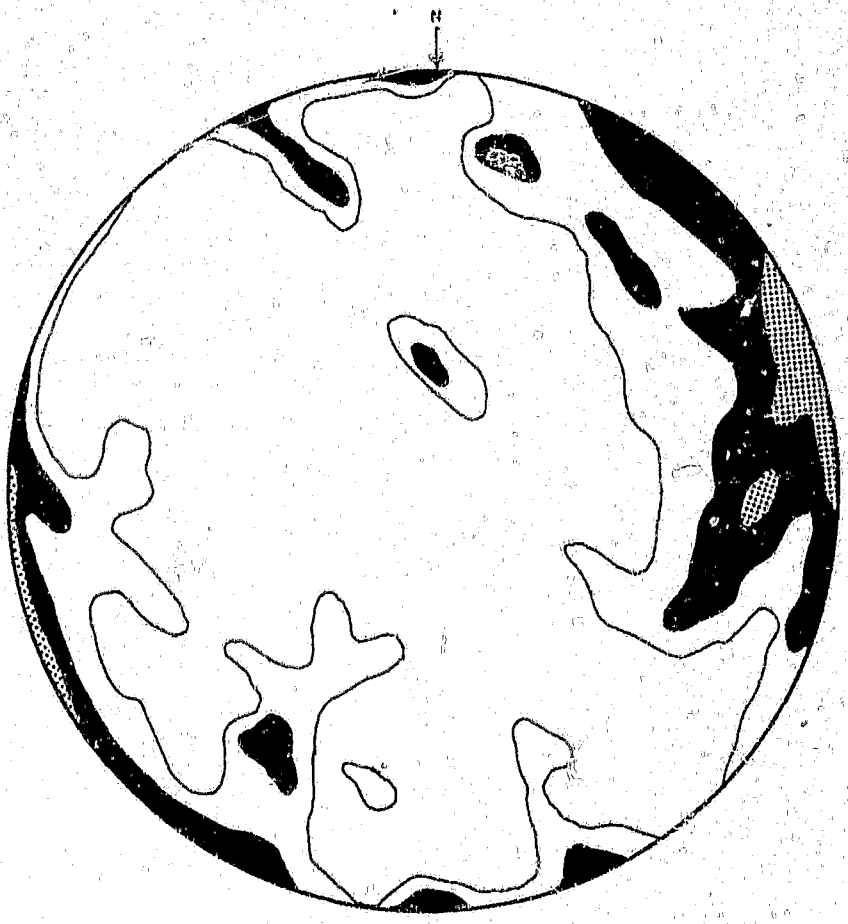
show an autoclastic deformation (Plate 33). They often displace earlier fractures and dykes, but differ from (b) in being well developed and readily visible in the granite (Plate 23).

(b) Short fractures, causing minor displacement of lamprophyre and aplite dykes, but not discernable in the granite (Plate 22). This suggests that heat emanating from the magma either once more rendered the granite plastic, or caused recrystallisation and annealing of the dislocations. Late injection of granitic material has also taken place along late fractures in the granite (Plate 34).

Fig. 21.

FIG 21

STEREOGRAM OF FOLIATION PLANES IN THE GNEISS



404 OBSERVATIONS

>3% CONTOUR OF FOLIATION PLANE POLES.

3% "

2% "

1% CONTOUR OMITTED

WIDE SCATTER OF PLOTS DUE TO MINOR FOLDING ATTRIBUTED TO THE ULTRABASIC & GRANITE INTRUSIONS

Structures in the Gneiss.

The greater proportion of the gneiss displays a distinct foliation, having a strike of 330°-360°, and dipping steeply to the east (Fig. 21). The banding or foliation is normally of the order of a few millimetres in width, consisting of layers of quartz and sausauritised felspar, alternating with varying concentrations of mica and amphiboles (Plates 35 and 36). The quartz-rich bands frequently stand out as resistant ribs on the weathered surface. Local changes in the gneiss foliation, when mapped in detail, have proved extremely useful in analysing the structural history of the area.

Bulawayan/Gneiss Contact.

Near the contact with the Bulawayan rocks, the gneiss foliation can be seen to swing parallel to the strike of the Bulawayan (Fig. 2). This does not agree with the findings of Keep (1929), who remarks on the angle that the gneiss foliation makes with the Bulawayan, and recording it as an unusual feature. Only in the extreme south of the area mapped (Fig. 2), did the gneiss foliation direction agree with the observations of Keep (op.cit.). The more normal orientation parallel to the Bulawayan strike, is probably due to the alignment of the foliation layers near the contact perpendicular to the regional compression.

Plate 35.



Fine gneiss foliation parallel to the hammer handle, being cut by jointing.

Plate 36.



Displacement of the gneiss foliation, with younger granite material infilling transverse fractures.

Two ages of folding have been established in the gneiss near the Bulawayan contact. In a tributary of the Shabi river, an early anticlinal structure trends parallel to the Bulawayan strike, and plunges SSE. This feature can be traced for 100 feet along strike, and is thought to link up with an anticlinal structure in the gneiss further south. It appears that the gneiss foliation was initially moulded by the main compressive force, and finally folded.

Later minor folds were developed at right angles to the anticlinal structure described above. These folds at one outcrop were found to plunge WSW at 24°. Possibly they may have developed through the slight upheaval of the marginal rocks during the emplacement of the granite. It appears certain that these WSW trending folds are later than the formation of the Bulawayan eugeosyncline, having been superimposed on an earlier fold structure, and having formed at right angles to the regional compressive force direction.

The development of tear faults striking ENE in the Bulawayan, emphasises the strong horizontal compressive forces operating during this period. These faults do not displace later acid intrusives, e.g. aplites or quartz veins.

Evidence for the gneiss having already developed a preferred lineation prior to the Bulawayan Orogeny, can be

seen in the banded gneiss pebbles that occur in the Bulawayan basal conglomerate.

Amphibolite.

The amphibolite occurrence is thought to represent a pre-Bulawayan ultrabasic or basic intrusion, possibly of Sebakwian age. It has been subjected to the forces which led to the formation of the gneiss basement, with which it has a diffuse contact. At the southern extremity of the amphibolite it grades into a hornblende-gneiss, with the hornblende crystals orientated parallel to the surrounding gneiss lineation. Remnants of amphibolite are found for considerable distances into the gneiss (Plate 37 & Fig. 23d).

The Effect of the Shabani Ultrabasic Intrusion on the Gneiss.

On the northern contact the gneiss is discordant with the Ultrabasic, the latter cutting the gneiss foliation at a high angle. On the southern side, due to the alignment of the gneiss foliation with the Bulawayan formation, the gneiss banding is intersected at a lower angle, or may be parallel.

The Shabani Ultrabasic dips at an angle of $\pm$ 50° to the south in the western area, compared with $\pm$ 30° south in the central Shabanie Mine portion. Folding of the Ultrabasic in the central area, with the fold axis parallel to the

Plate 37.



Amphibolite remnants (black) in gneiss near the gneiss/granite contact.

main intrusion, has been suggested by Laubscher (1963) to account for the Ad Valorem and Prince of Wales ultrabasic outliers.

There is no evidence of folding in the western extremity of the Ultrabasic. Displacement of the gneiss, arising from the intrusion of the Ultrabasic west of the Honeybird Mine, has however been taken up by small scale rupturing and folding. The faulting of the banded gneiss footwall, shows regular displacement northwards on the eastern side of the north trending shear planes. Conversely, in the hangingwall gneiss, the main movement is south on the eastern flank of similar shears. Due to the thickening of the Ultrabasic sill eastwards, these would be the natural displacement features, if the gneiss had deformed as a brittle host during the intrusion of an Ultrabasic wedge.

The Effect of the Granite Intrusion on the Gneiss.

Axial planar traces in the gneiss foliation have been interpolated wherever there has been sufficient data. In the gneiss bordering the SE contact of the younger granite, two such axial planes converge southwards in a 'V' formation. From the map (Fig. 2), the granite shows a slight outward bulge in this area, which appears to have uplifted the adjacent gneiss border. This slight uplift of the gneiss

Plate 38.



Younger granite (white) emplaced parallel to the gneiss foliation direction.

Plate 39.



Small scale fracturing and displacement of leucocratic band in the gneiss.

is further supported by the change in dip of the foliation to the west, and its alignment to the granite contact.

The axial planes of minor fold axes in the marginal gneiss have also been found to plunge at a flat angle away from the granite contact, indicating that doming has taken place. From these structures, the slope of the dome appears to vary between 10°-21°.

Lateral expansion of the western 'nose' of the Sibozo granite is reflected in the crumpling of gneissic banding in this area, with cleavage developing in the less competent bands.

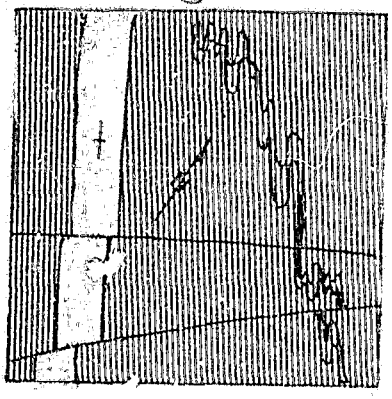
The granite/gneiss contact is well exposed on the southern granite border. In one locality, a tongue of granite has flowed along a curving fissure into the gneiss. The following observations and deductions have been made from a detailed examination of this exposure, and verified by contact features observed elsewhere.

(1) Some of the quartz bands in the gneiss have formed by the permeation of quartz and felspar along foliation planes. A noticeable increase in these bands occurs in the gneiss as the granite contact is approached from the SE. It is therefore often difficult to distinguish the original banding from these late injection bands, away from the contact (Plate 38). Variations in vein widths, and the fact that pink perthitic mineral assemblages have a lower

Fig. 22.

FIG 22

(A)



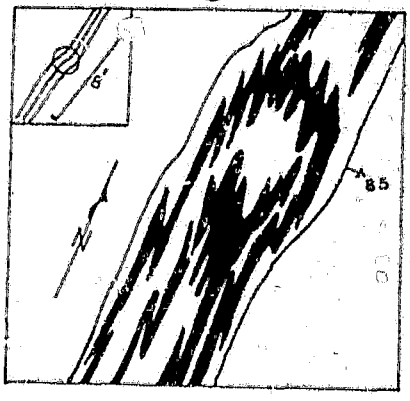
PTYGMATIC FOLDING OF EARLY QUARTZ VEIN IN THE GNEISS FORMED BY THE REHEATING OF THE GNEISS BY THE YOUNGER GRANITE

GRANITE VEIN

GNEISS

5 feet

(B)



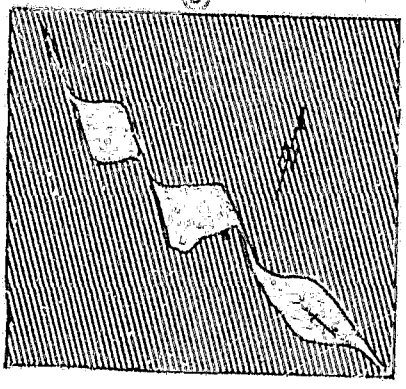
COMPLEX FOLDING OF THE GNEISS NEAR A SLIGHT FLEXURE IN THE FOLIATION. (INSET)

FELSIC LAYERS

MAFIC LAYERS

2 INCHES

(C)



DIABASE DYKE D[illegible]CED BY SHEARING PARALLEL TO THE GNEISS FOLIATION

DIABASE DYKE

GNEISS

5 feet

AMPHIBOLITE ROCK WITH A PREFERRED MINERAL ORIENTATION PARALLEL TO THE GNEISS FOLIATION

AMPHIBOLITE

GNEISS

300 feet

(D)

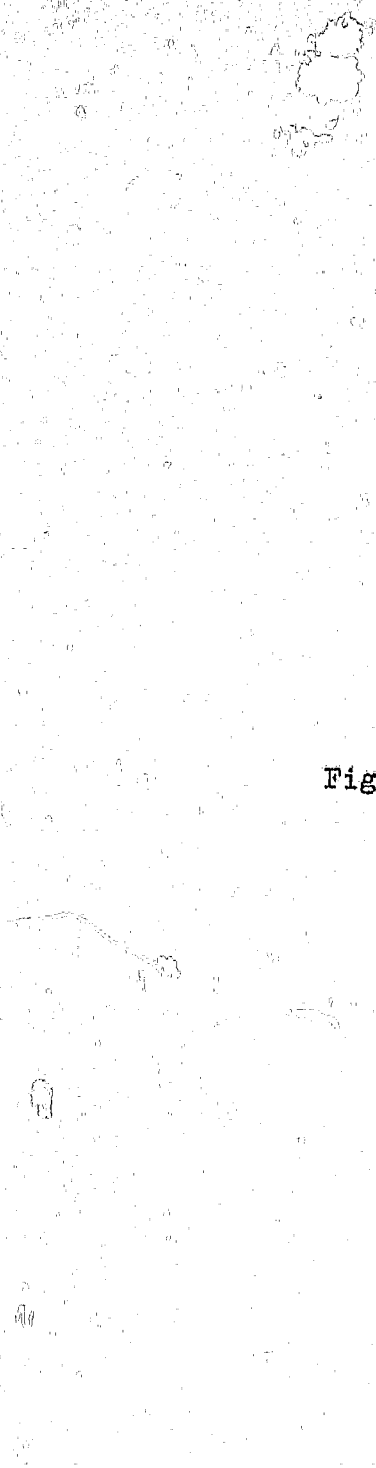


degree of fracturing, are features used in identification.

(2) Prior to the intrusion of the granite tongue (Fig. 18), fracturing developed, making a large angle with the gneiss foliation. This feature has been observed in other gneiss exposures near the granite contact. From the displacement of the banding, the gneiss appears to have been fractured into narrow strips, which have been 'shunted' away from the granite intrusion (Plate 39). Feather joints are occasionally associated with these small shears, which may have originated from a slight upheaval of the gneiss during the granite emplacement.

(3) Fractures or shear zones, parallel to the granite contact, appear to have acted as thermal channelways. Their effect is to soften the gneiss in the immediate vicinity, which results in ptygmatic or slump folding of the gneiss quartz bands (Fig. 22a), and may eventually completely obliterate the local foliation. The importance of this feature is stressed, because it provides an indication of the temperature of the granite, and the physical state of the gneiss host rock during the granite emplacement. Read (1931) and Wilson (1952) consider that ptygmatic veins are formed during the injection of quartz veins, whereby 'buckling' takes place when the vein encounters a resistant rock. Other writers believe the veins are contorted when plastic, and enclosed in a more

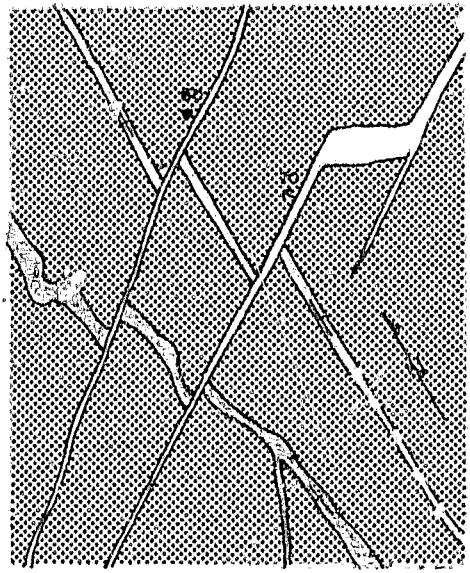
ductile country rock. In either case, a softening of the host rock has taken place when the quartzo-felspathic minerals were in a liquid or plastic state.



Figs. 23A & B.

SOME AGE RELATIONSHIPS OF MINOR INTRUSIVES IN THE YOUNGER GRANITE

FIG 23A



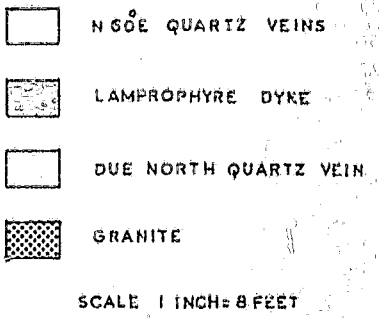
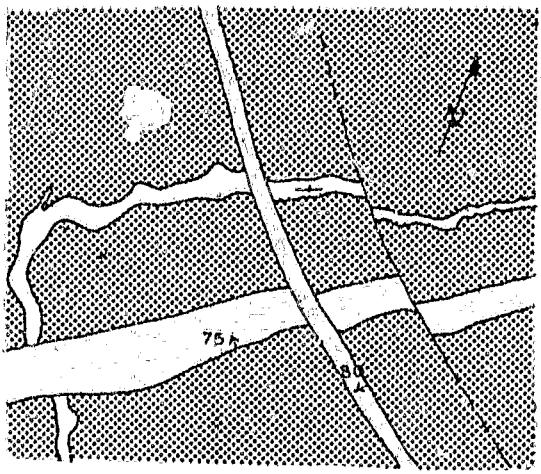
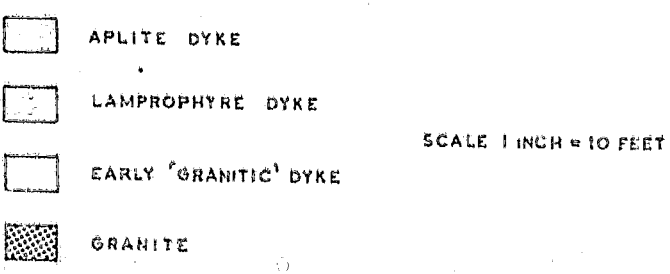


FIG 23B





Quartz Veins.

Quartz Veins Associated with the Younger Granite.

Two sets of quartz veins associated with the younger granite intrusion have been identified in the area. These are summarised below:-

(1) The earliest group strike parallel to the elongation direction of the granite, i.e. N35° - 65°E, and dip vertically. They usually form small, narrow veins, with a short strike length; an exception being a prominent 15-25 ft. wide 'buck' quartz vein in the NW granite area (Fig. 2). They are of no economic interest, consisting almost entirely of a barren, milky white quartz, with a small amount of pink perthitic felspar. These veins are the oldest in the granite, and frequently displace the lamprophyres (Fig. 23). Slickensiding is occasionally developed along the vertical vein walls.

(2) By far the most distinctive and prolific are the north-trending quartz veins. Variations in strike may occur from N5°W to N10°E, but in general they follow the gneiss foliation direction with a vertical to 80°E dip. Although they are predominently composed of a white glassy quartz, they contain similar mineral assemblages to those found in the granite. They are often associated with simple pegmatite and aplite-pegmatite composite veins, but again have no economic value.

The quartz veins have been correlated with the granite

emplacement, and represent a residual siliceous concentrate. Having a low viscosity, the solutions would escape along joint planes in the granite, and then along the gneiss foliation planes, in which major fractures, parallel to the foliation, would have formed during the development of the Bulawayan eugeosyncline and the emplacement of the granite.

Although these quartz veins are indisputably later than the Shabani Ultrabasic, one of the anomalies encountered in field mapping is their tendency to 'die out' at the Ultrabasic talc footwall contact. Having a vertical to 80°E dip, and a true thickness of up to 100 feet, these veins can be traced along a continuous, or slightly faulted strike, for several miles (Fig. 1). It is proposed that these prominent quartz veins are associated with the talc zones in the Shabani Ultrabasic, and with the formation of chrysotile asbestos, for the following reasons:-

(a) The strike of the steeply dipping veins has been guided by the gneissic foliation, and therefore solutions taking this path would be arrested by the Ultrabasic intrusive barrier. These confined solutions probably formed the irregular bodies of quartz, frequently found in the footwall talc zone of the Ultrabasic, and in the adjacent gneiss footwall in the central and eastern areas.

(b) The primary fracture pattern in the Ultrabasic consists of talc shear zones, dipping at $\pm$ 70° to the footwall, and

generally striking W to NW, i.e. nearly parallel to the strike of the Ultrabasic intrusion. Therefore, carbonate-rich, siliceous hydrothermal solutions encountering the Ultrabasic intrusive, would initially flow upwards along the footwall contact, which dips at 30-50°S, and finally along the intersecting shear zones; i.e. the siliceous solutions would infiltrate along the established fracture pattern, forming the talc-carbonate zones and footwall.

(c) Aplites and pegmatites found underground are related to the period of younger granite intrusion. Therefore, it is logical to suppose that the quartz veins, which are also associated with the granite and are far more prolific in the gneiss, must have also reached the main Ultrabasic body, and are now represented by the talc zones.

(d) In order for chrysotile fibre to form in the quantity found at Shabani, an abundant and steady source of hydro-thermal solutions, spread over a considerable period of time, is required. The period of chrysotile formation coincides with the intrusion of the younger granite, and the necessary time requirement would concur with the cooling of the granite and the emission of siliceous solutions.

(e) The disappearance of large, post-Ultrabasic quartz veins at the Ultrabasic footwall contact, requires an explanation, and reason (b) is the only logical answer.

(f) The width, (30-100'), and strike of the talc zones in

the Ultrabasic is comparable to the size of quartz veins in the gneiss. Furthermore, both features are later than the intrusion of the diabase dykes.

(g) Narrow aplite and pegmatite veins can be found underground, and they are intruded parallel to the talc zones, e.g. Block 7 orebody (170 Section). Furthermore, pegmatite remnants have been found within a talc zone (Zone C). The strike of these acid intrusives is therefore completely discordant with the strike of similar bodies in the gneiss.

(h) Occasionally aplite and quartz veins can be traced along strike from the gneiss into the Ultrabasic as talc zones, e.g. (Fig. 1) Birthday area. Near the Honeybird Mine, these veins have been followed from the granite through the gneiss to the Ultrabasic footwall (Fig. 2).

(i) The central portion of the Shabani Ultrabasic is the main fibre-bearing area. Solutions would naturally become trapped more in the centre, than on the margins.

Mineralised Quartz Veins.

A third set of quartz veins occur in the mapped area (Fig. 2), trending N313° - 335°, with a vertical to 70°E dip. They are sub-parallel to the elongation of the Bulawayan geosyncline, and displace all previously described pegmatite, aplite and quartz veins. In contrast to the earlier quartz veins, they are slightly mineralised, and the quartz has a distinctive glassy blue colour. One vein,

at the Warrik claims, has been traced from the Bulawayan to the granite contact, on the margin of which it disappears, having diffused along fractures and joint planes in the granite.

Due to the depth of oxidation, fresh specimens of the mineralised quartz were difficult to obtain. On the Warrik claims, the shafts are filled with water to within 20-30 feet of surface; above this line the vein is completely oxidised. The weathered rock appears as a low grade copper-iron gossan. Specimens of a poorly fractured quartz did however show remnants of pyrite, chalcopyrite and galena.

Intensive prospecting, in the form of exploratory trenches and pits, has been carried out on these veins, due to their encouraging limonitic surface outcrop. Panning of several outcrops was attempted, but only traces of colour were obtained.

These low grade quartz reefs are believed to be part of the regional gold vein network, representing offshoots from the major gold bearing channels. This supposition is supported by the following observations:-

(a) There is only one period of gold mineralisation established in the District, and this is taken to be late Bulawayan or Shamvian age. With one exception this period is post-diabase dyke formation. (The exception is the Hazard Mine, where an offshoot from the main reef displaces

a diabase dyke).

(b) The loci of the gold mineralisation appears to be in the Bulawayan rocks. Gold is also found in the adjacent gneiss, but only along major shear planes, and even then does not extend any great distance into the gneiss, e.g. the Sabi, Sabi Vlei and Canada gold mines. From these major channelways in the gneiss, smaller offshoots carrying erratic and generally low grade values would occur, e.g. the Dove and Warrik claims.

(c) Many of the gold bearing veins are distinguished by a blue, glassy quartz, heavily fractured and stained with iron oxides, features characteristic of the 313° - 335° veins.

Plate 40.



Micrograph of a polished section showing gold (white) in magnesite (grey). The gold has formed along cleavage planes in the magnesite. Shabanie Mine. X 70.

Economic Minerals found in the Shabani-Belingwe District.

Gold Mineralisation.

Large numbers of gold bearing quartz veins occur throughout the Shabani-Belingwe District. Gold mining opened up this part of Southern Rhodesia in the 1890's, and before these early pioneers, the Ancients, had found and worked most of the gold mines known today. Unfortunately the capriceous dispersion of gold values, coupled with bad mining practice in some cases, has resulted in the premature closure of most of these gold mines.

Gold has been found mainly in rocks of the Bulawayan Series and in the neighbouring gneiss. It has also been found underground on Shabanie Mine, associated with late-cutting shear zones in the footwall talc and adjacent gneiss (Plate 40). There have been no signs of gold mineralisation to date in the intrusive granite.

Two gold prospects were examined near the granite/gneiss contact, and these are described below.

The Dove or Dover Claims.

These were described by Keep in 1929, who gave them a favourable report. The claims are situated on low lying gneiss between the granite hills ½ mile to the NW, and the ultrabasic hills 1 mile to the SE. The vein widens from 18 inches to 5 feet, and strikes from N33°-38°E for at least 4000 feet, although it is not heavily mineralised

Plate 41.



Micrograph of chalcopyrite core (white), being replaced by covellite (dark grey) with a rim of chalcocite (light grey). Dove Claims. X 120. Polished section.

Plate 42.



Micrograph of growth rings in chalcopyrite. Dove Claims. X 120. Polished section.

for this entire length. The dip of the vein is from 30°SE to vertical, and follows a shear zone in the gneiss. On the widest part of the reef an 80° inclined shaft has been sunk, but could not be entered due to flooding to within 15 feet of surface. Both the hanging and footwall gneiss is highly sheared and incompetent.

Samples taken across the reef were crushed and panned; they showed traces of gold up to 5 dwt. Polished sections were made from two specimens, and the following sulphide minerals identified:- pyrite, chalcopyrite, covellite and chalcocite. The chalcopyrite forms the core of covellite crystals, whose rim is being replaced by chalcocite (Plates 41 & 42). Gold was not identified in the specimens examined. The gangue mineral is quartz, having a dark blue glassy colour, with numerous fractures and cavities stained with iron, copper oxides. Galena was identified in other hand specimens collected from exploratory trenches and pits. If the water problem can be overcome, and providing the gold values persist with depth, this property would still be worth further investigation.

The Warrik Claims.

These claims are situated approximately ½ mile south of the granite/Bulawayan contact. They consist of two parallel quartz reefs, 7 and 8 feet wide, striking N28°W and dipping 75°E. The veins are separated by 15 feet of

serpentinised ultrabasic rock. The exploratory shafts have been developed on the eastern vein, and a deep pit excavated on the western vein. Their strike has been proved for 700 feet, and can be traced for a further 500 feet in a native mealie field. The claims were registered in Bulawayo in 1960, but have since lapsed; at present the shafts are filled with water to within 20 feet of surface.

Specimens were taken from both reefs, which contain the normal dark blue quartz, deeply pitted with limonite discolouration. The main minerals identified were pyrite and chalcopyrite; no visible gold could be seen under the binocular microscope, although traces were found in panned samples. The hangingwall contact for both veins is a soft, green chlorite schist with scattered garnets. The garnets are deep red, and rarely exceed 3-6 mm. in size; they approach almandine in composition, and are identical to those garnets found in narrow talc bands in the gneiss. The footwall contact consists of a highly sheared serpentine for 3 feet, which then grades into a massive, competent blue-black serpentine.

These reefs appear to be low grade, but they have a long strike length, only 60 feet of which has been opened up by pits and cross-trenches. It is therefore possible that higher values could be found along strike, particularly in more structurally favourable areas, e.g. at the

intersection of earlier dykes or fractures.

Other Neighbouring Gold Mines.

A study of the gold mineralisation in the District was undertaken during the early stages of this investigation, for it appeared that with the establishment of a late period of granite intrusion, a source for the hydrothermal, gold bearing quartz veins had been found. This view is no longer held by the writer, who believes that the gold mineralisation occurred after the intrusion of the younger granite, and is therefore probably late Shamvian. With the exception of the Dove claims, the developed gold properties fall outside the main area studied.

Keep, in 1928, visited twenty-four small workings or claims, of these, eighteen were mining a glassy, dark blue quartz reef, having a predominently NE strike. Fifteen of these properties have been visited by the writer. Although only two are still in production (the Sabi and Canada Mines), several others are being reviewed following the recent offer of Government assistance. In all cases it has only been possible to examine the surface workings, the underground workings being no longer accessible.

Gold mineralisation is unevenly distributed on all the properties, and this was undoubtably the main reason for their closure. A brief description follows of three typical small workings.

These mines, originally called the F.B., the Ivy and Gatling Hill Mines, and recently repegged as Planet, Extra and Gatling Hill North, occur 13 miles west of Shabani and between ½-1 mile west of the Ngesi low level bridge on the Bulawayo road. Several reefs are found on each property, generally consisting of a dark blue shattered quartz. They have a N-NE strike, and dip from vertical to 70°E. The host rock is a highly sheared chloritic schist of Bulawayan age.

Pyrite is normally found in these veins and in the adjacent wallrock. On the Ivy Mine, gold has been reported to be associated with the pyrite, but polished sections from this mine fail to confirm this association. At Gatling Hill, ¼ inch pyrite crystals were found in the schist, and due to weathering and leaching, this rock has a distinctive pitted appearance. Copper staining was also observed in these rocks, associated with narrow veins of chalcopyrite.

In the Gatling Hill area, in addition to the dark blue quartz veins, a later series of white quartz veins occur. These strike due east and dip vertically. They are composed of a hard glassy quartz, within which are pockets of a fine, mineralised, sugary quartz. Samples taken from these veins have had a reported assay value of 1 oz. per ton. Without the aid of assay plans, it is difficult to reconstruct which reefs contain good values, for the area

is such a complex maze of trenches, pits and shafts. Several samples were taken from these claims without any notable results.

Chrysotile Asbestos.

This is the main economic mineral in the Shabani-Belingwe District. On Shabanic Mine, five fibre grades are produced, with cross fibres ranging up to 2" long and occasionally exceeding this. Short chrysotile fibre seams are extremely widespread throughout the area, and can be found in the Bulawayan serpentines and in the isolated ultrabasic bodies north of Shabani. Brittle and harsh chrysotile fibres are mined at Shabani, but they are not exploited elsewhere. During the last three years a slight recession hit the asbestos industry in Southern Rhodesia, and although there has been a slight improvement in 1964, several asbestos properties have remained closed, e.g. the Honeybird Mine and Slip Mine.

Possible Commercial Exploitation of Minerals Associated with Chrysotile Asbestos Mining.

Carbonated Serpentine.

This rock may have an application as a refractory mineral. Serpentines are being used in Europe for this purpose, as they have a high magnesium and relatively low iron content. It would appear that the Shabani carbonated

serpentine would be ideally suited for this role. In the Honeybird area a completely serpentinised rock occurs. This attractive dark green rock has been used occasionally as a local building stone.

Olivine Flour.

Where material is required to withstand extremely high temperatures, olivine flour has been used. In parts of the Shabani Ultrabasic hangingwall the dunite has not been serpentinised, and therefore this rock could produce a pure olivine concentrate, providing the rock is finely milled in order to extract the magnetite.

Talc Rock (Soapstone).

There has been no commercial exploitation of this rock to date, as unfortunately the talc is invariably contaminated with magnesite, and is normally sheared. Nevertheless, selected samples have been used for sculpturing.

Economic Minerals other than Gold and Chrysotile Asbestos.

Galena.

This mineral is frequently associated with the gold bearing veins. Local concentrations of galena do occur on certain properties, e.g. Road Claims, 5 miles SE of Shabani. Assays carried out recently on these claims, show a high silver content that is evidently contained in the crystal lattice. These claims are found on the gneiss, and have

been intermittently mined for gold. The reef consists of a fractured, glassy blue quartz, containing pyrite, chalcopyrite and galena. With the recent increase in the price of lead and silver, galena could become a profitable by-product from the gold mining operation.

Antimony.

This mineral, in the form of stibnite, is at present being mined on the east bank of the Ngesi river where it crosses the Shabani-Belingwe road; on the site originally described by Keep (1929). The stibnite had not been mined commercially until the beginning of 1964, when the world market price of antimony rose sharply. Higher antimony values were encountered with depth on this property, and several parallel reefs have been discovered adjacent to the first reef. These recently exposed veins strike approximately east, with a vertical dip, and outcrop well above the river elevation. They strike parallel to the foliation of the host rock, which is a deep green Bulawayan schist. This assists in clean mining along strike, and the ore is further upgraded by hand sorting. Because of the vertical dip and the narrow width of the veins (1-3 feet), this will probably remain a profitable small working, but it is unlikely to ever produce a large tonnage.

Sand Dredging.

Large quantities of sand are deposited in the Shabi

river and tributaries annually, during the seasons' rains. The sand derived from the younger granite is a distinctive pink variety, with an extremely low mafic mineral content. This sand is pumped from impounded reaches of the river, and used extensively in all local concrete construction work. (Milled serpentine rock is undesirable as a concrete aggregate, due to its reaction with cement).

CONCLUSIONS.

Regional Setting of the Shabani Gneiss.

Macgregor lists four main cycles for the Rhodesian Archaean granites. Briefly these are as follows:-

(a) The oldest is a tonalitic gneiss, represented by the Rhodesdale batholith (Rhodesian Midlands). It is thought to be post-Sebakwian but pre-Bulawayan, and may have caused the granitisation of Sebakwian sediments in certain localities.

(b) The second period is a post-Bulawayan tonalitic gneiss, grading into a grey massive tonalite, e.g. Zwimba batholith (Midlands). These granites have a higher soda content than the older granites.

(c) The Matopos porphyritic adamellite represents the third suite, and is thought to be a refusion of the older granites during late Bulawayan or Shamvian times, with an addition of potash.

(d) Finally, the fourth group appears to be a straight refusion of the tonalitic gneisses, without any addition of material. They are represented by the fine to medium-grained tonalites of the area SW of Gwanda, and they are partly massive and partly porphyritic.

In the Shabani District, the grey medium-grained gneiss can be compared with the oldest of Macgregor's Series. It is definitely pre-Bulawayan, for the Bulawayan sediments

have been deposited on its peneplaned surface; but whether it is post-Sebakwian is unknown as no absolute age determinations have been carried out.

Laubscher (1963), doubts the existence of the Sebakwian, as there is to date no evidence of sedimentary features in the gneiss. The writer has established a pre-gneiss basic intrusion which could be of Sebakwian age. Macgregor proposed that the strict adherence to the doctrine Uniformitarianism is unjustified in early Archaen times, for the differentiation of sediments must decrease with increasing age. Therefore, the earliest sediments would contain poorly sorted arkoses and greywackes, which could explain the remarkably even texture and composition of the ancient gneiss around Shabani. Furthermore, due to their granitic assemblage, these early sediments would be very susceptible to granitisation, in which basic and ultrabasic bodies could remain as 'resistors', e.g. the amphibolite zone in the Shabani gneiss.

Development of the Bulawayan Geosyncline, and Origin of the Younger Granite.

The Bulawayan System was then deposited on the peneplaned surface of the gneiss, and due to the thin sialic crust, sedimentation associated with isostatic readjustment of the gneissic foreland, led to the formation

of the Bulawayan geosyncline.

Downwarping of the crust, with further movement of gneiss bordering the area of sedimentation, would cause sympathetic shearing and fracturing of the gneiss parallel to the geosynclinal axis. These fractures would be transmitted through the solid sialic shell into the sima and upper mantle.

As a result of the sudden local release in pressure, basic and ultrabasic material would flow upwards along these planes of weakness, forming the basic pillow lavas, and serpentinite flows and sills in the Bulawayan sediments, as well as the Shabani Ultrabasic body and outliers. With further development of the geosyncline, possibly following on the outpouring of great volumes of submarine spilitic lavas, the lower parts of the sialic crust would be at a sufficient depth for palingenesis to take place. The remobilised granitic material would tend to migrate into areas of lower pressure, initiated by tensional conditions, and guided by major fractures, particularly in the marginal gneiss foreland.

According to the structural setting and composition, the Shabani younger granite could have such an origin, and could possibly be correlated with the third suite of Macgregor, viz. the Matopos adamellite.

The two granite bodies (Fig. 1) are emplaced along a

Plate 43.



Pegmatite in the gneiss, possibly formed by 'sweeping' of the gneiss into a fracture. Elongation of quartz (dark grey mineral) parallel to the gneiss foliation direction, being replaced by microcline-perthite (white to light grey).

distinct N30°-40°E strike, which forms a right angle to the local synclinal axis of the Bulawayan rocks. The main regional compressive force operated in a NE-SW direction during the evolution of the Bulawayan geosyncline. Laubscher (1963) states this direction to be N24°E, and Mehliss (1963) as N30°E.

This dominant stress direction would create tensional conditions in a parallel NE plane, with a strong shear pattern (N 0°-10° E) developed at an acute angle to this regional compressional direction. The granite magma was primarily moved into this low pressure tensional area, while the later pegmatite and aplite dykes and quartz veins infilled the shear planes. Wilson (per. comm. 1964) considers that many of these late quartz - pegmatite veins were formed as a result of the "sweating" of the gneiss into foliation planes, by remobilisation of the potash rich fraction (Plate 43). This form of lateral secretion on a small scale, is comparable to that envisaged during the anatectic origin of the younger granite.

Mode of Emplacement of the Younger Granite.

The younger granite in the Shabani district is well exposed, whilst the contact with the gneiss can be located in the Shabi river, and elsewhere can be mapped to within a few feet. Similarly, the contact between the Bulawayan

rocks and the granite has also been established within narrow limits.

It was apparent throughout the field examination of the granite and surrounding rocks, that its emplacement has been guided along distinct structural lines. Furthermore, although uplifting and fracturing of the contact rocks has occurred, such deformation is on a very small scale, and the granite appears to have permeated into position, rather than been injected. Numerous dykes and veinlets of granite, and late granite differentiates within the surrounding rocks, testify to its mobility.

The following observed geological features listed below illustrate several aspects of the granite controversy. (1) The straight undeflected continuation of an iron-rich quartz vein in line with the adjacent banded ironstone (Figs. 1 & 2), is a striking feature completely bisecting the younger granite. In the northern portion of the granite, banded ironstone undisturbed in strike has been found within the granite, and is a continuation of the iron-rich quartz vein. The enclosing granite is of the normal pink variety.

This feature can be accounted for in various ways. Magmatists would regard the banded ironstone/iron-rich quartz vein as a structurally undisplaced inclusion. It may represent a 'barrier' contact for the larger eastern portion of the granite at this level, with granite magma

breaking through it at lower levels, and becoming emplaced on the other side. A relatively quiet emplacement of the magma is required in order to leave this narrow body undisturbed by flow movements within the magma.

Transformationists, on the other hand, would consider this feature as a natural 'resistor' comparable to the basic dykes found in the Donegal granite (Pitcher & Read 1960).

(2) The overall even texture and composition of the granite contrasts with the absence of any flow structures. Lacy (1960) maintains that convection currents in the melt would ensure an even texture and composition. To achieve the same result, Korzhinsky (1960) notes that during the metasomatic replacement of collateral rock by a granite magma, a filtration of solutions can occur (osmotic distillation). Under these conditions, the granite is purified from the assimilated components of the country rock. Furthermore, a rise in the potentials of alkalies, especially potassium, occurs in these solutions resulting from the dissolution of strong bases, e.g. calcium, magnesium and iron, during the replacement of limestone and basic rocks. This process would explain why a distinct contact rock (microcline-microperthite - hornblende rock) occurs between the younger granite and the amphibolite, whereas at the granite and gneiss contact there is hardly

any replacement of the gneiss by potash felspar. Furthermore, the deep red colouration of the microperthite near the amphibolite/granite contact is explained by the assimilation of ferrous iron into the crystal lattice from the iron-rich amphibolite, and subsequent oxidation to ferric by hydrothermal solutions (Emmon 1953).

(3) The low degree of thermal metamorphism surrounding the younger granite, suggests that the granite was emplaced as a low temperature melt. This observation is supported by the presence of microcline-microperthite rather than orthoclase in the granite. If this were true, then the granite magma should have had a high viscosity, causing disruption of the country rocks during its intrusion, which is not the case.

It can be argued that the gneiss, being of a granitic composition, would hardly be affected by the younger granite intrusion. Thin sections cut from the contact gneiss show the original felspars to be completely altered, and only quartz and intruded granite minerals could be identified. Similarly, serpentinisation of the Bulawayan greenstone rocks at the granite contact completely masks any thermal metamorphic zoning.

(4) Two distinct sets of fracture patterns occur in the two areas of the younger granite, separated by the iron-rich quartz band (Figs. 2 & 20). It is probable that

these fractures have developed through the effect of dynamic forces acting on different encompassing host rocks; i.e. the Bulawayan rocks, due to their structural setting, would develop a different stress field to that of the foliated gneiss, and these stresses would be reflected in the younger granite.

The younger granite studied in detail at Shabani, only represents the south western extremity of a distinct line of granites, extending 12 miles north-east to the Lundi river. Similar younger granites have been examined in the Mashaba District, e.g. the Chinoia Hill granite, which has a comparable strike and composition to that of the Shabani granite.

The portent of the previous statement, is the economic significance of the younger granite intrusion. At Shabani and Mashaba there are large deposits of chrysotile asbestos, and during the investigations of Laubscher (1963) the relative age of these deposits was established. This work disproved Keep's (1929) hypothesis that the gneiss was later than the Shabani Ultrabasic, and that the gneiss provided the hydrothermal solutions necessary for the formation of the asbestos. Keep (op.cit.) did recognise a younger granitic phase, but considered this to be an apophysis of the gneiss. Laubscher derives his hydrothermal solutions from the Bulawayan sediments, but the writer believes that

the younger granite is the ideal source for the chrysotile-forming hydrothermal solutions. It was therefore important to attempt to understand the formation and emplacement of the granite, in order to decide whether it was feasible to intrude a low temperature, fluid, granitic magma, having a composition and texture comparable to the Shabani younger granite.

Melting.

It is believed that melting can take place at depths of 12-21 Km. in the earth's crust, in geosynclinal areas where the initial thermal gradient is of the order of 30°C./Km. (Tuttle and Bowen 1958). Depending on the water content, which appears to be a critical factor, complete melting will take place if there is 9-10% water available. Where the water content is of the order of 2%, only partial melting will take place, and greater depths would be necessary. Depths of 28-30 Km. are envisaged in this latter case (Lacy 1960).

According to Tuttle and Bowen, experimental studies in the system $NaAlSi_3O_8$ - $KAlSi_3O_8$ - H_2O, show that the alkali felspars form a complete series of solid solutions above 660°C., but below this temperature they unmix rapidly, especially in the presence of water vapour under pressure. Therefore, assuming a thermal gradient of 30°C/Km, a minimum

depth of 22 Km is required for the melting of the Shabani granite, where homogenous felspars occur with unmixed perthitic varieties. This figure is further confirmed by Bowen and Tuttle, who quote 21 Km depth for the complete melting of a wet granite containing 9% water, at a thermal gradient of 30°C. With a 2% water content, total melting is believed to occur at depths of 50 Km. Obviously a steeper thermal gradient, e.g. 50°C/Km, will reduce considerably the critical depth required for complete melting. Thermal zones are known to exist within the earth's crust, giving wide variations in temperature, and furthermore, Buddington (1959) believes that during Precambrian times there was a far steeper geothermal gradient in the lithosphere. The initial melting of the Shabani younger granite therefore probably took place during the final stages of the Bulawayan geosynclino, when the sialic layer beneath the geosynclinal root had been sufficiently depressed to cause anatexis or palingenesis. Temperatures of the order of 900-1,000°C are thought to have occurred at a depth of approximately 30 Km, giving a geothermal gradient of 30-33°C/Km, with an initially low water content of 2%.

Migration of the Derived Granite Melt.

The absence of strong folding in the Bulawayan sediments

suggests epeirogenetic movement to have been the dominant force. Macgregor (1951), considers the folding of the Rhodesian basement complex (i.e. the Bulawayan System in the Shabani-Belingwe area) to be principally due to gravity. With a relatively thin crust resting on a mobile substratum, the crust would sink at points of deposition, and the granites would rise around it. Certainly at Shabani, the shape and structures in the Bulawayan eugeosyncline are determined by the attitude of the encompassing batholiths.

Vening Meinesz (1955), believes that the development of a geosyncline takes the order of 20-40 million years, with continual compressive stress. Should relaxation of these crustal stresses occur before the catastrophic stage is reached, readjustment to isostatic equilibrium will take place, and the geosyncline will not become folded. This lack of strong orogenic forces would prevent any violent squeezing of the magma into the higher regions of the Crust. Instead, a slow upward migration is envisaged, guided by major fractures and shear planes.

A higher geothermal gradient is believed to occur within geosynclinal sedimentary rocks than in adjacent stable areas. Bowen (1947) states that relatively high temperatures would occur near the base of a geosyncline, as a result of the insulation of the overlying blanket of sediments. Therefore the temperature loss during the

upward passage of the granite magma from its source to the base of the geosyncline, e.g. at a depth of 10 Km, will probably be of the order of 200°C. Partial crystallisation will have occurred with possibly a slight differentiation of the melt taking place. Increased mobility of the magma, due to an increase in water, will occur during the selective refusion of the sediments. This water would be obtained from the connate water in the sediments, and the breakdown of sedimentary minerals. Goodspeed (1952), estimates that kaolinitic minerals release approximately 14% water during their conversion to felspar. The viscosity of the magma would probably be reduced from 10^{10} to 10^{9} poises (Lacy 1960), therefore assisting its upward migration; final emplacement being along tensional fractures arising from the formation of the Bulawayan geosyncline and associated diastrophic readjustments. Similar alkali younger granites have been described by Greenwood (1951), in the Plateau Province of Northern Nigeria, where he considers their intrusion to have occurred by large scale stoping along concentric fractures, without disturbance of the older rocks. The common association of granites with ultrabasic intrusions, might be due to a higher residual thermal gradient in these areas.

As previously mentioned, the granite, although guided by large scale fracturing and its emplacement possibly assisted by stoping, must have been extremely fluid not to

cause any major deformation of the invaded rocks. Bowen believes that a potassium-rich granitic fraction is capable of absorbing water in considerable excess of 9-10% water, i.e. the normal amount thought to occur in a saturated granitic melt.

Cooling and Crystallisation.

It is thought that the Na-K. granitic solutions in addition to having a low viscosity, could also have been emplaced at a relatively low temperature. Chayes (1956) found that the compositions of granites falling in the low temperature trough of Bowen and Tuttle's triangular diagram had the following assemblage:- quartz 40%, orthoclase 30% and albite 30%. This composition is comparable to that of the Shabani granite, except that instead of orthoclase the potash felspar is microcline-microperthite. The low temperature of these granite solutions would explain the absence of thermal metamorphism at the contact.

The fine infiltration of the surrounding rocks was eventually arrested by the progressive lowering of the temperature of crystallisation. Initially, the main granite mass would develop a chilled margin, represented by the graphic texture at the granite/gneiss contact.

Accumulation of hydrothermal solutions would be increased during crystallisation, and these would escape

continuously along suitable fractures and planes of weakness in the gneiss and Bulawayan rocks.

In the final stages, the residual granitic melt would consist predominantly of quartz and water, with accessory potash and soda felspar. This volatile material would stope its way along joint planes in the granite, forming aplite and aplite-pegmatite composite veins. As cooling continued, dilatational shrinkage fractures developed at right angles to the elongation of the granite. Many of these fractures were infilled by the lamprophyre dykes, whose occurrence is restricted to the granite.

Nature of the Granitic Solutions.

According to Tuttle and Bowen (1958), sodic or potassic silicate melts are capable of absorbing large quantities of water, which correspondingly decreases their respective viscosities. Magmatic granites with a high concentration of sodic or potassic minerals have been frequently observed in the field, and it would appear that a separation of these two fractions has in many instances taken place (Walker and Mathias 1946; Hunter 1956; Marmo 1955; Gates and Scheerer 1963). In the latter case, a trend from soda-rich to potash-rich graphic granite was established. This agrees with the findings of Soper (1963) in the Rogart Igneous Complex, where a calo-alkaline line of liquid descent from

tonalite, to porphyritic granodiorite, to biotite granite, to aplite was discovered (Fig. 10). Therefore from a magmatic origin, there is considerable evidence for a granitic series descending from a calc-alkaline source to a sodic and potassic differentiate, with a final separation of this concentrate. This division into two fractions is supported by laboratory evidence, whereby unmixing of a soda-potash silicate melt occurs on cooling below 660°C. Whitfield (1959), considers that there are two distinct end members in a granite series, based on composition and textural features, one end being represented by a granite containing equal quartz, plagioclase and potash felspar, with minor amounts of mica, i.e. comparable to the Shabani younger granite. Therefore it is argued that the series would be fortuitous by any metasomatic process, but easily explai d by magmatic differentiation.

Most of the field evidence put forward by the magmatist has been used to support the views of the proponents of granitisation. However, although selective remobilisation is a logical argument for the origin of the Shabani granite, the minor crystallisation trends observed at Shabani, reflect a chemical process akin to magmatic differentiation. Therefore, although metasomatic fluids or granitising solutions are attractive, especially the latter, in that they possibly have a low temperature and great mobility, a

magmatic emplacement is suggested for the Shabani Younger Granite.

In the writer's opinion, Shand (194) has the most acceptable views on the nature of the granitic solutions forming the Shabani granite. He observed that an aqueous solution of alkaline salts is commonly found in quartz inclusions. From this, he deduced that the 'magma' is a form of granitic emulsion, consisting of an emulsion of crystals in two immiscible liquids, the larger volume having a moderate to low alkaline content, and the other a high alkaline content. Emulsions are known to have a high mobility at a relatively low temperature, two important factors in the Shabani granite emplacement.

The Origin of the Chrysotile-forming Carbonated Hydrothermal Solutions.

It is the writer's contention that the source of the hydrothermal solutions which led to the formation of the chrysotile fibre deposits is the younger granite, and not the connate waters in the Bulawayan sediments, as proposed by Laubscher (1963). There are no known channelways linking the talc zones in the Ultrabasic with the Bulawayan sediments to the south, but there is every indication that there is a connection between the quartz and pegmatite veins associated with the granite, and the talc zones.

Lindgren (1935), considers that meteoric water in permeable sedimentary rocks may reach depths of 10,000 feet, but compaction will drive off considerable quantities of this water, during the early stages of the developing geosyncline. The formation of the asbestos deposits at Shabani is thought to be late Bulawayan, i.e. post diabase dyke intrusion, and therefore their development is inconsistent with the escape of the bulk of the sedimentary water. Furthermore the sediments themselves are poorly developed in the Bulawayan geosyncline near Shabani.

In the early stages of this investigation, it was thought that the granite was 'dry', a deduction based on its equigranular, medium-grained texture, and the low degree of thermal metamorphism on the surrounding country rocks. Had the granite been initially 'dry', it would have been correspondingly viscous, and its emplacement would have caused extensive dislocation and possible updoming of the contact rocks. The complete opposite has been found to be true, with the granite showing a remarkable mobility coupled with low temperature. These features have been described in detail under "Migration of the Derived Granite Melt", "Cooling and Crystallisation" and "Nature of the Granitic Solutions".

Evidence indicating the presence of hydrothermal solutions can be seen in the numerous aplite, pegmatite and

quartz veins emanating from the granite. Underground on Shabanie Mine these same features have caused comparable serpentinisation of the dunite, to that found adjacent to fibre seams.

The writer considers that the granite magma had a low viscosity, due to its initially high water content, which was probably in excess of 9-10%. This was increased by absorption of water from the Bulawayan rocks, and by reaction with clay minerals, during its upward migration. Carbon dioxide contained in the granite melt could become enriched by the replacement of carbonates present in the sediments and lavas, and by absorption of atmospheric carbonated water. In early Archaen times, it has been estimated that there was a far greater proportion of carbon dioxide in the atmosphere (Macgregor 1927). This water would be thoroughly incorporated in the magma, and t[illegible]e concentrated in regions of lowest pressure and temperature (Kennedy 1955).

Marey and Hasselgesser (1952), proved the high solubility of alkali silicates in superheated water, and as previously mentioned, a potash-rich granite as found near Shabani is capable of absorbing large volumes of water.

Therefore, it is proposed that the Shabani younger granite provided the source for the hydrothermal solutions that led to the formation of chrysotile asbestos. The

reasons are briefly summarised below:-

(1) Granite is capable of absorbing large volumes of water, which would become concentrated in low pressure areas.

(2) The emplacement of the granite is contemporaneous with the formation of chrysotile asbestos at Shabani. Furthermore, a similar geological setting occurs at Mashaba, another important chrysotile asbestos mining centre.

(3) Escape of the hydrothermal solutions contained in the granite would be along existing fracture patterns, e.g. the joints in the granite, foliation planes in the gneiss, and the footwall fracture patterns in the Shabani Ultrabasic. Therefore, it is logical to assume that the aplites, pegmatites and quartz veins in the granite will follow the gneissic foliation, until they are restricted by the Ultrabasic footwall. These siliceous, carbonated solutions would lead to the steatisation of the footwall, and the formation of the talc zones in the Ultrabasic. The low temperature of these solutions, probably below 400°C, is in agreement with the low temperature emplacement of the younger granite. Crystallisation of chrysotile would occur in sub-parallel fractures to the intrusion, under suitable structural conditions. This would possibly be assisted by the primary layering of olivines within the dunite, for it is thought significant by the writer, that the cross-fibre seams parallel the strike and dip of the

Ultrabasic.

(4) It has been estimated that the cooling time for a granite stock comparable to the Shabani occurrence, is in the region of 150,000 years (Lacy 1960). During part of this time hydrothermal solutions will be driven off for long periods. Although the consolidation time for a granite given above could vary considerably, it is obvious that a long time interval is involved, which is critical for the formation of the extensive asbestos deposits at Shabani. Slow cooling of the Shabani granite is indicated by the formation of microcline-microperthite rather than orthoclase (Marmo 1958).

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2 Maps

The Gubbins

THE GEOLOGY OF AN AREA NEAR SHABANI, RHODESIA, WITH SPECIAL EMPHASIS ON AN OCCURRENCE OF YOUNGER GRANITE.

by

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